Analyzing the Function-topology Relationship in the Drosophila Segment Polarity Network

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Biomolecular networks have to perform their functions robustly. A robust function may have preferences in the topological structures of the underlying network. We carried out an exhaustive computational analysis on network topologies in relation to a patterning function in Drosophila embryogenesis. We found that while the vast majority of topologies can either not perform the required function or only do so very fragilely, a small fraction of topologies emerges as particularly robust for the function. The topology adopted by Drosophila, that of the segment polarity network, is a top ranking one among all topologies with no direct autoregulation. Furthermore, we found that all robust topologies are modular-each being a combination of three kinds of modules. These modules can be traced back to three sub-functions of the patterning function and their combinations provide a combinatorial variability for the robust topologies. Our results suggest that the requirement of functional robustness drastically reduces the choices of viable topology to a limited set of modular combinations among which nature optimizes its choice under evolutionary and other biological constraints.